REMARKS

In view of the above amendments and the following remarks, reconsideration and further examination are requested.

The specification has been reviewed and revised to make a number of editorial revisions. No new matter has been added. Enclosed is a marked-up copy of sections of the original specification labeled "***Version with Markings to Show Changes Made***" indicating the changes.

Applicants hereby request that the Information Disclosure Statement filed with the Patent Office on November 21, 2002 and the Information Disclosure Statement filed concurrently with this Amendment be considered by the Examiner. Applicants also request that the Examiner return initialed copies of the PTO-1449 forms which were filed as part of the Information Disclosure Statements.

Claim 4 has been rejected under the doctrine of obviousness-type double patenting as being unpatentable over claims 1 and 2 of U.S. patent number 6,207,549. Claim 4 has been canceled. As a result, withdrawal of this rejection is respectfully requested.

Claim 7 has been rejected under 35 U.S.C. §112, first paragraph, as containing subject matter not adequately disclosed in the specification. Claim 7 has been canceled. As a result, withdrawal of this rejection is respectfully requested.

Claims 4, 5, 7-9, 11 and 12 have been rejected under 35 U.S.C. §103(a) as being unpatentable over admitted prior art (APA) in view of Yasuzato (US 5,060,853), Khandros (US 5,476,211) and Khandros (US 5,917,707).

Claims 4, 5, 7-9 and 11 have been canceled and claim 12 has been amended to further distinguish the present invention over the references relied upon by the Examiner. Further, new dependent claims 21-24 have been added.

The above-mentioned rejection is submitted to be inapplicable to amended claim 12 for the following reasons.

Claim 12 is patentable over the combination relied upon by the Examiner, since claim 12 recites a semiconductor arrangement having, in part, a first protrusion having a formed portion formed by forming a melted portion of a wire with a capillary and solidifying the melted portion, and a wire material portion comprising a portion of the wire in a vicinity of the melted portion, the

wire material portion extending from a vertex portion of the formed portion downward from the vertex portion and being bonded to the formed portion, and wherein the wire material portion does not contact an IC electrode or a circuit forming surface. The combination of APA, Yasuzato, Khandros ('211) and Khandros ('707) fails to disclose or suggest a wire material portion as recited in claim 12.

In the combination, APA discloses a bump electrode. The bump electrode has a ball bond portion 105 and a wire portion 101. The ball bond portion 105 is bonded to an electrode 104 which is bonded to a semiconductor element 170. The wire portion 101 extends up from the ball bond portion 105 and is then bent downward to one side of the ball bond portion 105. The portion of the wire portion 101 that is bent downward to the one side of the ball bond portion 105 is connected to both the ball bond portion 105 and the electrode 104. (See Figs. 17A-17D).

The rejection relies on the wire portion 101 as corresponding to the wire material portion recited in claim 12. (See page 6, lines 10-12 of the Office Action). However, as discussed above, it is apparent that the wire portion 101 contacts the electrode 104. Therefore, APA fails to disclose or suggest a wire material portion as recited in claim 12.

One of the benefits of not having the wire material portion come into contact with the electrode is that during formation of the bump electrode, material from the electrode can contaminate a remainder of the wire comprising the wire portion not used in forming the bump electrode due to the contact. This contamination could prevent any later created bump electrode created from the remainder of the wire portion from properly forming a ball bond portion. (See page 3, paragraph [0011]).

Also in the combination, the rejection relies on (1) Yasuzato and (2) Khandros ('211) and Khandros ('707) as disclosing (1) a bump electrode having a protrusion that extends beyond a planar area and (2) a plurality of protrusions that extend beyond a planar area, respectively. However, even if these statements are accurate, none of Yasuzato, Khandros ('211) or Khandros ('707) discloses or suggests a wire material portion as recited in claim 12.

Therefore, it is apparent that the combination of APA, Yasuzato, Khandros ('211) and Khandros ('707) fails to disclose or suggest the invention as recited in claim 12.

Because of the above mentioned distinctions, it is believed clear that claims 12, 13 and 21-24 are patentable over the combination relied upon by the Examiner. Furthermore, it is submitted that the distinctions are such that a person having ordinary skill in the art at the time of invention would not have been motivated to make any combination of the references of record in such a manner as to result in, or otherwise render obvious, the present invention as recited in claims 12, 13 and 21-24. Therefore, it is submitted that claims 12, 13 and 21-24 are clearly allowable over the prior art of record.

In view of the above amendments and remarks, it is submitted that the present application is now in condition for allowance. The Examiner is invited to contact the undersigned by telephone if it is felt that there are issues remaining which must be resolved before allowance of the application.

Respectfully submitted,

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12. (Amended) A semiconductor arrangement comprising [one] a bump electrode having [two protrusions] a first protrusion and a second protrusion bonded to an IC electrode on a circuit forming surface of a semiconductor element, [and]

wherein said [two] first and second protrusions are [brought] in contact with or [put] close to [one] an electrode on a circuit board when the semiconductor element is mounted on the circuit board,

wherein said first protrusion has a formed portion formed by forming a melted portion of a wire with a capillary and solidifying the melted portion, and a wire material portion comprising a portion of the wire in a vicinity of the melted portion, said wire material portion extending from a vertex portion of said formed portion downward from said vertex portion and being bonded to said formed portion, and

wherein said wire material portion does not contact the IC electrode or the circuit forming surface.

13. (Amended) A semiconductor arrangement as claimed in [Claim] claim 12, wherein the electrode on the circuit board and said bump electrode are electrically connected to each other.

(with respect to the IC electrode); moving the bonding capillary sideways and then downward; bonding a wire to the ball bond portion; and cutting the wire, the wire being prevented from coming in contact with a periphery of the ball bond portion (i.e. with portions around the ball bond portion) other than the ball bond portion itself by presetting a descent position of the bonding capillary to a position higher than a ball bond forming position.

[0014] According to a second aspect of the present invention, there is provided a method of forming a bump electrode on an IC electrode comprising: forming a ball bond portion on an IC electrode by a wire bonding apparatus; moving a bonding capillary upward; moving the bonding capillary sideways and then downward; bonding a wire to the ball bond portion; and cutting the wire, the ~~were~~ wire being prevented from coming in contact with a periphery of the ball bond portion other than the ball bond portion itself by setting a chamfer angle of the bonding capillary not greater than 90 degrees to make the ball bond portion have a height greater than a diameter of the wire.

[0015] According to a third aspect of the present invention, there is provided a method of forming a bump electrode on an IC electrode comprising: forming a ball bond portion on an IC electrode by a wire bonding apparatus; moving a bonding capillary upward; moving the bonding capillary sideways and then downward; bonding a wire to the ball bond portion; and cutting the wire, the wire being prevented from coming in contact with a periphery of the ball bond portion other than the ball bond portion itself by setting a chamfer diameter of the bonding capillary greater than a diameter of the ball bond.

[0016] According to a fourth aspect of the present invention, there is provided a method of forming a bump electrode on an IC electrode comprising: forming a ball bond portion on an IC electrode by a wire bonding apparatus; moving a bonding capillary upward; moving the bonding capillary sideways and then downward; bonding a wire to the ball bond portion; and cutting the wire, the wire being prevented from coming in contact with a periphery of the ball bond portion

device.

[0039] According to a 27th aspect of the present invention, there is provided a method of fabricating a semiconductor device as defined in the 26th aspect, wherein said good-or-bad test of said electrical connection is executed by determining the presence or absence of the conductive adhesive based on pick-up image information of said outwardly protruding portion picked up by said image pick-up device.

[0040] According to a 28th aspect of the present invention, there is provided a method of fabricating a semiconductor device as defined in the 26th aspect, wherein said good-or-bad test of said electrical connection is executed by confirming the operation of said semiconductor element by electrically bringing a contact into contact with said outwardly protruding portion instead of using said image pick-up device.

[0041] According to a 29th aspect of the present invention, there is provided a method of fabricating a semiconductor device as defined in the 28th aspect, wherein confirmation of operation of said semiconductor element is executed by a diode characteristic test.

19 [0042] According to a 30th aspect of the present invention, there is provided a method of fabricating ~~frabricating~~ a semiconductor device as defined in any of the 25th through 29th aspects, wherein a flat surface portion is formed at the vertex portion of each of said first protrusion and said second protrusion before said conductive adhesive is provided, and then said conductive adhesive is provided on the flat surface portion.

[0043] According to a 31st aspect of the present invention, there is provided a method of fabricating a semiconductor device as defined in any of the 25th through 30th aspects, wherein solder is used in place of said conductive adhesive.

[0044] With the above-mentioned arrangement of the present invention, the wire does not come in contact with the periphery of the ball bond portion other

(First Embodiment)

[0077] Figs. 1A-1C show sectional views of processes of a bump electrode forming method according to a first embodiment of the present invention, where an Au wire 101 is prevented from coming in contact with ~~ay~~ any portion other than the ball bond portion 115 when the Au wire 101 is bonded to the ball bond portion 115.

[0078] In Figs. 1A-1C are shown the Au wire 101 as one example of a wire, a bonding capillary 113, an IC electrode 104 and the ball bond portion 115.

[0079] The operation of the method of forming a bump electrode on the IC electrode will be described next with reference to Figs. 1A-1C and 2.

[0080] Fig. 1A is a sectional view showing when the ball bond portion 115 is formed on the IC electrode 104 of the board 170, Fig. 1B is a sectional view showing a state in which the Au wire 101 is bonded to the ball bond portion 115 by the bonding capillary 113 located in a descent position, and Fig. 1C is a sectional view of a bump electrode 116.

[0081] Fig. 2 is a sectional view of the bonding capillary 113, in which are shown a chamfer angle 107, an outer radius 108, a chamfer diameter 109, a face angle 110 and a cone angle 111.

[0082] First, the position in height of the bonding capillary 113 in a ball bond forming stage is stored in the apparatus in Fig. 3A, and the position in height of the bonding capillary 113 when the bonding capillary 113 is moved down to bond the Au wire 101 to the ball bond portion 115 is preparatorily set to a position higher than the position in the ball bonding stage.

[0083] As shown in Fig. 3A, the capillary 113 is driven by a supersonic generating device 152 such as a voice coil in a capillary driving device 150 to minutely move up and down around a fulcrum 151. The capillary driving device 150 is set on an X-Y table 153 which is driven in X and Y directions by motors 154 and 155. The operations of the motors 154 and 155 and a driver 180 for driving the supersonic generating device 152 are controlled by a controller 181.

[0084] The operation of the embodiment described above will be described with the reference to Figs. 3A and 3B based on the ball bonding method. An ordinate axis of Fig. 3B shows movement (height) in the Z direction perpendicular to the X and Y directions and an abscissa axis thereof shows time of the operation of the embodiment.

[0085] It is noted that the ball bonding method is also described in detail in a seventh embodiment described below. In Fig. 3B, first, the controller 181 controls the motors 154 and 155 so that the capillary 113 is moved to a torch 160 to form a ball at the lower end of the wire 101. Then, the capillary 113 is moved to a first wire coordinate (X,Y,Z) as a reference position for forming a bump electrode 116 (bump) on the electrode 104 of the board 170 by control of the controller 181 based on the data stored in a memory 182 of the controller 181. The first wire coordinate is located just above the position of the electrode 104 in the Z direction. At this time, a clamp 159 for clamping the wire ~~1~~ 101 set above the capillary 113 in the capillary driving device 150 is open so as to not clamp the wire ~~1~~ 101. Then, the driver 180 of the supersonic generating device 152 is controlled by the controller 181 so that the capillary 113 is moved down toward the electrode 104 at a first step (1) of Fig. 3B by the supersonic generating device 152. When the capillary 113 has been moved down by a predetermined distance stored in the memory 182, the descending speed of the capillary 113 is lowered to prevent the capillary 113 from contacting the electrode 104 with such a large force that damages it. That is, the capillary 113 is slowly moved down at a second step (2) toward the electrode 104. When the capillary 113 contacts the electrode 104, the capillary 113 continues to descend until the driver 180 detects a predetermined load from the capillary 113 by detecting a current running through the driver 180, and after the load detection, the driver 180 sends a first contact signal to the controller 181. Based on the reception of the first contact signal, the controller 181 controls the driver 180 to apply supersonic vibration to the capillary 113 with a first

load to form a ball bond portion 115 on the electrode 104 as shown in Fig. 1A at a third step (3). Then, after the formation of the ball bond portion 115, the capillary 113 is moved up at a higher speed than the descending speeds of the second and third steps (2) and (3), at a fourth step (4).

[0086] Then, at the start of a fifth step (5), the clamp 159 starts to clamps the wire ~~1~~ 101 and continues to clamp it during a predetermined period of time. The capillary 113 is looped and moved down as shown in Fig. 5D at the fifth step (5) while the wire ~~1~~ 101 is clamped by the clamp 159 for the period of time and after the period of time the wire ~~1~~ 101 is free from clamping.

[0087] If necessary, correction of the movement amount(s) is performed by the controller 181 depending on the shape of the ball portion 115 or the like at a sixth step (6).

[0088] Then, at a seventh step (7) of searching the slope of the ball bond portion 115, the capillary 113 is further moved down at a lower speed to prevent the capillary 113 from contacting the slope of the ball portion 115 with such a large force that damages it. At that time, as described above, the lowest position in height of the capillary 113 when the capillary 113 is moved down to bond the wire ~~1~~ 101 to the slope of the ball bond portion 115 is preparatorily set to the position higher than the lowest position in the ball bonding stage. Accordingly, based on the preparatorily set position of the capillary 113, the movement amount of the capillary 113 in the Z direction is previously determined and stored in the memory 182. Thus, based on the stored position and movement amount data, the controller 181 controls the supersonic generating device 152 to move the capillary 113 downward at the lower speed in order to bond the wire ~~1~~ 101 to the slope of the ball bond portion 115, the movement amounts of the capillary 113 in the X and Y directions from the center of the ball portion 115 are also previously determined and stored in the memory 182 such that the bonding wire can be bonded to the ball bond portion with no space circumscribed by the bonding wire (see Figs. 1B and 1C). Thus,

based on the stored position and movement amount data, the controller 181 controls the motors 154 and 155. When the capillary 113 contacts the slope of the ball portion 115, the capillary 113 continues to descend until the driver 180 detects a predetermined load from the capillary 113 by detecting a current running through the driver 180. After the detection, the driver 180 sends a second contact signal to the controller 181. Based on the reception of the second contact signal, the controller 181 controls the driver 180 to apply supersonic vibration to the capillary 113 with a second load to connect the wire 101 ~~1~~ to the slope of the ball bond portion 115 as shown in Fig. 1B at an eighth step (8). After the connection of the wire 101 ~~1~~ to the slope of the ball bond portion 115, the capillary 113 is moved up while the clamp 159 does not clamp the wire ~~1~~ 101 at a ninth step (9). After the ninth step (9) is completed and the clamp 159 clamps the wire ~~1~~ 101 again, the capillary 113 is moved upward to break the wire ~~1~~ 101 and moved to a next coordinate (X,Y,Z) above the next electrode 104 at a tenth step (10). Then, at an eleventh step (11), another ball is formed at the lower end of the wire ~~1~~ 101 by the torch 160. Then, the first to eleventh steps (1) through (11) are repeated on or above the next electrode 104.

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[0089] By thus presetting the descent position of the bonding capillary 113 to a position higher than the position in the ball bonding stage, the Au wire 101 can be prevented from coming in contact with the IC electrode portion 104 even when the Au wire 101 is pressed by the capillary 113 when the Au wire 101 is cut by the capillary 113.

(Second Embodiment)

[0090] As shown in Fig. 2, by setting the chamfer angle 107 of the bonding capillary 113 to an angle of not greater than 90 degrees, the height of the ball bond portion 115 is made greater than the diameter of the Au wire 101.

[0091] By thus setting high the ball bond portion 115, the Au wire 101 can be prevented from coming in contact with the electrode portion 104 when the Au wire 101 is cut by the bonding capillary 113.

(Third Embodiment)

2 **[0092]** As shown in Fig. 2, by making the chamfer diameter 109 of the bonding capillary 113 greater than the ball bond portion diameter, the ball bond portion 115 ~~115~~ can be prevented from spreading outwardly in the ball bonding stage, thereby allowing the bonded state of the Au wire 101 to be stabilized. By thus stabilizing the bonded state of the Au wire 101, the Au wire 101 can be prevented from coming in contact with the electrode portion 104 when the Au wire 101 is cut by the bonding capillary 113.

(Fourth Embodiment)

10 **[0093]** As shown in Fig. 2, by setting the thickness of the tip end portion of the outer radius portion 108 of the bonding capillary 113 to, for example, 10 μm or smaller and making it have a tapered shape, the cutting force can be concentrated on the tip end of the outer radius portion 108 in cutting the Au wire 101. Since the Au wire 101 is cut by a small cutting force as described above, the Au wire 101 can be prevented from coming in contact with the electrode portion 104 in the cutting stage.

(Fifth ~~sixth~~ Embodiment)

14 **[0094]** As shown in Fig. 1B, by setting the angle of the outer radius portion so that the outer radius portion of the bonding capillary 113 comes in uniform contact with the slope of the ball bond portion 115, the effect of bringing the bonding capillary 113 in contact with the Au wire 101 is improved, so that the Au wire 101 can be stably cut.

(sixth Embodiment)

[0095] As shown in Fig. 13, by bringing the bonding capillary 113 in contact with the Au wire 101 above the center portion of the slope of the ball bond portion 115, the Au wire 101 can be bonded and cut in a stabilized state even when the Au wire contact is varied.

[0096] With reference to Fig. 1D, the preset descent position of the bonding capillary 113 to the position higher than the ball bond forming position is

the direction of height from the electrode 2. It is to be noted that Fig. 4 shows the case where the terminal end 52 extends to a position located slightly higher than the height of the vertex portion 41 of the first protrusion 40. Fig. 15 shows the case where the terminal end 52 extends in height to a position located approximately halfway between the position in height of the end 51 and the position in heigh of the vertex portion 41 of the first protrusion 40.

[0102] The terminal end 52 of the second protrusion ~~so~~ 50 comes in contact with no adjacent electrode 2 of the semiconductor element 1.

[0103] By thus providing the first protrusion 40 and the second protrusion 50 at one bump 3, the area of the vertex portions 7 of the bump 3 can be increased, and as described in detail later, the connection area when connecting the above-mentioned bump 3 to the electrode of the circuit board by means of a conductive adhesive can be increased, so that the connection resistance value can be reduced. Furthermore, the amount of transfer of the conductive adhesive onto the bump 3 can be increased, and this eliminates the possible occurrence of a defective electrical connection, allowing the conduction reliability to be improved.

[0104] The bump 3 of the above-mentioned type is formed approximately through the processes in Steps (each indicated by "S" in the figure) 1 through 3 as shown in Fig. 6, mostly in accordance with the ball bonding method. That is, in Step 1, the length of a recrystallization region as described later is controlled by controlling the discharge time, thereby melting the wire 10. In Step 2, the first protrusion 40 is formed of the melted wire on the electrode 2. In Step 3, the second protrusion 50 is further formed. These operations will be described in more detail below.

[0105] As shown in Fig. 5A, a wire 10 which has a wire diameter of, for example, 25 μm and is made of a material of, for example, gold is extended by about a length II from the tip end portion 9a of the capillary 9. It is to be noted that the above-mentioned length II is 450 μm, i.e., the projection length in the

can also be extended beyond an extension line of the outer end surface 1b of the periphery of the semiconductor element 1. It is to be noted that the orientation of the terminal end 52 is effected by the operation of the capillary 9. In regard to the bump 300, a bump at which the terminal end 52 is extended beyond the extension line of the outer end surface 1b of the periphery of the semiconductor element 1 is denoted by a bump 310 as shown in Fig. 10. Further, the portion which belongs to the wire 10 and extends beyond the extension line of the outer end surface 1b is denoted by an outwardly protruding portion 53.

[0126] By thus orientating the terminal end 52 to the peripheral side of the semiconductor element 1, the terminal end 52 does not extend toward the adjacent electrode 2 in the semiconductor element 1. Therefore, the terminal end 52 is not brought in contact or short-circuited with the adjacent electrode 2 when the conductive adhesive 18 is transferred to the bump 310. Therefore, the orientation of the terminal end 52 to the peripheral side of the semiconductor element 1 can assure the amount of transfer of the conductive adhesive 18 and prevent the possible occurrence of the short circuit as described above by virtue of the provision of the second protrusion 50 in addition to the first protrusion 40.

[0127] Further, a semiconductor device can also be fabricated by forming the bump 310 on the electrode 2 of the semiconductor element 1 as described above in Step 1~~1~~ shown in Fig. 11 and connecting the bump 310 onto the electrode 20 of the circuit board 19 in a face-down mounting manner in Step ~~1~~2. When fabricating the semiconductor device as described above, the terminal end 52 is neither brought in contact or short-circuited with the adjacent electrode 2 in the semiconductor element 1 having the bump 310.

[0128] Furthermore, the second protrusion 50 of the bump 310 has the outwardly protruding portion 53. For the above reason, when the bump 310 is connected to the electrode 20 on the circuit board 19, its connection area is

greater than that of, for example, the bump 300. Therefore, the connection strength can be made higher and the connection resistance value can be made lower.

4 **[0129]** Furthermore, in a semiconductor device 610 in which the semiconductor element 1 having the bump 310 is connected to the circuit board 19 (see Fig. 12), a test process for testing the performance of the electrical connection of the bump 310 to the electrode 20 on the circuit board 19 can be provided as one fabricating process of the semiconductor device 610 as shown in Step 13 in Fig. 11. This test will be described below.

10 **[0130]** For example, when the semiconductor element 1 having the bump 300 is mounted on the circuit board 19 in the face-down mounting manner, the terminal end 52 of the second protrusion 50 is not protruding from the outer end surface 1b of the periphery of the semiconductor element 1. Therefore, the portion in which the bump 300 is connected to the electrode 20 on the circuit board 19 cannot be visually checked. When the semiconductor element 1 having the bump 310 is mounted on the circuit board 19 in the face-down mounting manner, the outwardly protruding portion 53 is protruding from the outer end surface 1b of the periphery of the semiconductor element 1. Therefore, the portion in which the bump 310 is connected to the electrode 20 on the circuit board 19 can be viewed via the outwardly protruding portion 53 and subjected to a visual test.

[0131] Furthermore, it is acceptable to automatically execute the above-mentioned visual test by means of a camera 25 and a visual tester 26 connected to the camera 25 as shown in Fig. 12. That is, the electrical connection of the bump 310 to the electrode 20 can be checked in a good-or-bad test by picking up the image of the portion in which the outwardly protruding portion 53 is connected to the electrode 20 by the camera 25, taking the image into the visual tester 26, and detecting the presence or absence of the conductive adhesive 18 in the connection portion by means of the visual